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[TITLE OF INVENTION] ELECTRODE, BATTERY, AND METHOD OF  
MANUFACTURING THE SAME

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[DOCUMENT TITLE] SPECIFICATION

[TITLE OF THE INVENTION] ELECTRODE, BATTERY, AND METHOD OF  
MANUFACTURING THE SAME

[SCOPE OF CLAIM FOR PATENT]

[CLAIM 1] An electrode, comprising:

a collector, and

an electrode layer which is formed by being laminated on the collector  
and contains an active material,

wherein the average thickness of an electrode plane defined as a region  
where the collector and the electrode layer are laminated ranges from 5 to 300  
 $\mu\text{m}$ , and

the maximum thickness of the electrode plane is 105% or less of the  
minimum thickness of the electrode plane.

[CLAIM 2] The electrode as claimed in Claim 1, wherein the average  
thickness of the electrode plane within 10 mm from a region where the electrode  
layer is not laminated on the collector is 104% or less of the average thickness of  
the electrode plane in a region other than the region mentioned above.

[CLAIM 3] The electrode as claimed in Claim 2, wherein the region where the  
electrode layer is not laminated on the collector is a region where a tab is

connected.

[CLAIM 4] The electrode as claimed in any one of Claims 1 to 3, wherein a ratio ( $\sigma/A$ ) of the standard deviation ( $\sigma$ ) of the thickness of the electrode layer to the average thickness ( $A$ ) of the electrode layer is 3% or less.

[CLAIM 5] The electrode as claimed in any one of Claims 1 to 4, wherein the electrode layer is formed by an inkjet method in which a liquid containing the active material is ejected in a form of a number of particles to have the particles adhered to a predetermined substrate.

[CLAIM 6] The electrode as claimed in Claim 5, wherein the substrate is the collector or a polymer electrolyte membrane.

[CLAIM 7] The electrode as claimed in any one of Claims 1 to 6, wherein the active material is a positive electrode active material composed of Li-Mn based composite oxide or Li-Ni based composite oxide.

[CLAIM 8] The electrode as claimed in any one of Claims 1 to 6, wherein the active material is a negative electrode active material composed of a crystalline carbon material or a non-crystalline carbon material

[CLAIM 9] A battery made by use of the electrode claimed in any one of Claims 1 to 8.

[CLAIM 10] The battery as claimed in Claim 9, wherein the battery is a rectangular battery formed by containing a battery constituting element comprising the positive electrode and the negative electrode in an exterior packaging material composed of a polymer metal composite film, and the average thickness of a portion where the battery constituting element is stored

within 10 mm from an end of the portion where the battery constituting element is stored is 104% or less of the average thickness of the battery at the portion where the battery constituting element is stored which is 10 mm or more away from the end of the portion where the battery constituting element is stored.

[CLAIM 11] The battery as claimed in Claim 9 or Claim 10, wherein the battery is a lithium secondary battery.

[CLAIM 12] An assembled battery formed by connecting a plurality of the batteries as claimed in any one of Claims 9 to 11 in series, in parallel, or in series and in parallel combined.

[CLAIM 13] Multiple assembled batteries formed by connecting a plurality of the assembled batteries as claimed in Claim 12 in series, in parallel, or in series and in parallel combined.

[CLAIM 14] A vehicle loaded with the assembled battery claimed in Claim 12, or the multiple assembled batteries claimed in Claim 13.

[CLAIM 15] A method of manufacturing an electrode containing a process of forming an electrode layer by use of an inkjet method, in which a liquid containing an active material is ejected to a predetermined substrate in a form of a number of particles to have the particles adhered to the predetermined substrate.

[CLAIM 16] The method of manufacturing the electrode as claimed in Claim 15, wherein the substrate is a collector or a polymer electrolyte membrane.

[CLAIM 17] The method of manufacturing the electrode as claimed in Claim 15 or Claim 16, wherein the liquid containing the active material is adhered twice

or more to the same location of the substrate to increase thickness of the electrode layer.

[CLAIM 18] The method of manufacturing the electrode as claimed in any one of Claims 15 to 17, wherein the particles are ejected by a change of a volume of piezoelectric elements.

[CLAIM 19] The method of manufacturing the electrode as claimed in any one of Claims 15 to 18, wherein the volume of the particles ranges from 1 to 100 picoliters.

[CLAIM 20] A method of manufacturing a battery, comprising:

a process of forming a negative electrode layer by use of an inkjet method in which a liquid containing a negative electrode active material is ejected in a form of a number of particles; and

a process of forming a positive electrode layer by use of the inkjet method in which the liquid containing a positive electrode active material is ejected in the form of a number of particles.

[CLAIM 21] The method of manufacturing the battery as claimed in Claim 20, further comprising:

a process of forming a polymer electrolyte membrane by use of the inkjet method in which a liquid containing a polymerization initiator and a polymer electrolyte raw material which forms a polymer electrolyte by a polymerization reaction induced by the polymerization initiator is ejected in the form of a number of particles.

## [DETAILED DESCRIPTION OF THE INVENTION]

[0001]

### [TECHNICAL FIELD]

The present invention relates to an electrode and a battery by use of the electrode. In particular, the electrode of the present invention is preferably used for a secondary battery as a motor driving power source of an electric vehicle or the like.

[0002]

### [PRIOR ART]

Recently, introduction of an electric vehicle ( hereinafter referred to as EV), a hybrid electric vehicle (hereinafter referred to as HEV), or a fuel-cell vehicle (hereinafter referred to as FCV) is strongly desired from a background of growing environment protection movement, and a motor driving battery for such vehicle has been developed. As the motor driving battery for such vehicle, a repeatedly rechargeable secondary battery is used. Since EV, HEV, or FCV requires high output and high energy density, it is practically impossible for a single large-size battery to cope with the requirement. Therefore, an assembled battery composed of a plurality of batteries connected in series is generally used. As a single battery constituting such assembled battery, a thin laminated battery is proposed (refer to, for example, Patent Document 1).

[0003]

The thin laminated battery is a battery which uses a metal sheet material as an exterior package of a lithium ion battery. Materially, the metal sheet material is a laminated sheet on which a metal thin film, a resin film, and a heat-sealing resin film are laminated. The metal thin film is constituted of an

aluminum foil or the like, and prevents exchange of a gas such as steam, oxygen, or the like inside and/or outside of the package. The resin film is constituted of polyethylene terephthalate or the like, and physically protects the metal thin film. The heat-sealing resin film is constituted of an ionomer or the like, and is used for tight sealing of the battery.

[0004]

Generally, the positive electrode or the negative electrode is produced by applying a coating fluid containing a positive electrode active material or a negative electrode active material onto a collector. In this case, although various kinds of coaters such as a roller coater or the like are used, quality of the battery is deteriorated by unevenness of the coating generated during the application by use of the coater. Specifically, there is a problem that heat dissipation characteristics of the battery become uneven and the battery is partially degraded. Further, in the battery having a partially uneven thickness, there is also a problem that the battery is easily resonated by vibration applied to the battery and a crack or rupture of the substrate is easily caused. In particular, in the battery applied to a vehicle, it is necessary that the battery characteristics are maintained over a long period of time of more than ten years.

[0005]

As means for reducing the unevenness of the coating of the electrode, for example, means for controlling viscosity of the coating fluid is proposed (refer to, for example, Patent Document 2). However, when a fluid containing the electrode constituting material is applied by use of a conventional coater, it is difficult to unify the coated film more than a certain level. For example, when intermittent coating is performed, a partial build-up of the electrode constituting material is generated and the film thickness tends to be partially thickened.



[0006]

Further, when the battery is applied to a use in which high output is required, such as to a vehicle or the like, it is necessary to reduce the thickness of the electrode, and to connect a number of batteries in series. However, it is difficult to produce the extremely thin electrode by use of the conventional coater.

[0007]

[PATENT DOCUMENT 1]

Japanese Patent Laid-Open No. 2003-151526

[PATENT DOCUMENT 2]

Japanese Patent Laid-Open No. 2002-164043

[0008]

[PROBLEM TO BE SOLVED BY THE INVENTION]

An object of the present invention is to provide an electrode which is thin and high in uniformity of film thickness.

[0009]

Further, another object of the present invention is to provide means for manufacturing the electrode.

[0010]

[MEANS FOR THE SOLUTION]

The present invention provides an electrode, comprising a collector, and an electrode layer which is formed by being laminated on the collector and contains an active material, wherein the average thickness of an electrode plane defined as a region where the collector and the electrode layer are laminated ranges from 5 to 300  $\mu\text{m}$ , and the maximum thickness of the electrode plane is 105% or less of the minimum thickness of the electrode plane.

[0011]

The present invention further provides a method of manufacturing the electrode including a process of forming an electrode layer by use of an inkjet method in which a liquid containing an active material is ejected to a predetermined substrate in a form of a number of particles to have the particles adhered to the predetermined substrate.

[0012]

[ADVANTAGE OF THE INVENTION]

The electrode according to the present invention is very thin and high in the uniformity of the film thickness. Therefore, the heat dissipation of the battery is uniform, and local degradation of the battery is hard to be generated. Crack or rupture of the electrode is also hard to be caused. If an electrode layer is formed by use of the inkjet method, density or thickness thereof can be precisely controlled, and a very thin electrode having high uniformity of the film thickness, which cannot be manufactured by a conventional coater, can be manufactured.

[0013]

[MODE OF CARRYING OUT THE INVENTION]

A first aspect of the present invention is an electrode, comprising a collector, and an electrode layer which is formed by being laminated on the collector and contains an active material, wherein the average thickness of an electrode plane defined as a region where the collector and the electrode layer are laminated ranges from 5 to 300  $\mu\text{m}$ , and the maximum thickness of the electrode plane is 105% or less of the minimum thickness of the electrode plane.

[0014]

Fig. 1 is a schematic view of an embodiment of the electrode of the present invention. Fig. 1 shows the electrode in which an electrode layer 102 formed by use of an inkjet method is laminated on a collector 104. It should be noted that Fig. 1 is exaggerated for the purpose of better understanding of the present invention. For example, although the electrode layer 102 is shown as if it is constituted by a number of particles, in order to show that the electrode layer 102 is formed by adhesion of particles ejected by the inkjet method, the electrode 102 is confirmed to be one layer when viewed by naked eyes. The electrode is sealed in an exterior packaging material, and a positive electrode tab and a negative electrode tab are drawn to the outside of the exterior packaging material. When the electrode layer 102 is laminated on the collector 104, for connecting the tab to the collector 104, a portion 106 where the electrode layer 102 is not laminated (hereinafter referred to also as uncoated portion) may be provided on the collector 104. Although the uncoated portion may also exist for a purpose other than the connection of the tab, a decrease in energy density of the battery is caused when the uncoated portion is increased. Therefore, preferable is that the uncoated portion is not provided as much as possible except for the portion where the tab is connected. However, it is not intended to prohibit the unavoidable generation of the uncoated portion due to a manufacturing reason.

[0015]

In order to form the electrode layer, conventionally, a coater such as a roller coater or the like has been used. However, it is impossible to form the electrode layer having the thinness and the uniformity of the thickness in a degree more than a certain level by use of the conventionally known coater. If description is made of the thinness, when the electrode layer is formed by the coater, if a coated film to be formed does not have a thickness of a certain level, a portion where the film is not formed is generated. If description is made of the uniformity of the thickness, when the electrode layer is formed by the coater, the film thickness tends to thicken at an end of the coating film. In other words, the coating film tends to thicken in an interface between the region where the coating film is formed and the region where the coating film is not formed.

[0016]

The present invention achieves the requirements of the thinning and the unification of the electrode layer, which have not been conventionally achieved, by adoption of the inkjet method. The inkjet method means a printing method in which liquid ink is ejected from a nozzle to have the ink adhered to a target subject. The inkjet method is classified into a piezoelectric method, a thermal inkjet method, and a bubble jet (registered trademark) method according to the methods by which the ink is ejected.

[0017]

The piezoelectric method is a method in which the ink arranged on a bottom of an ink chamber storing the ink is ejected from the nozzle by deformation of piezoelectric elements which are deformed by the flow of the

current. The thermal inkjet method is a method in which the ink is heated by a heat-generating heater and is ejected by energy of a steam explosion at the time when the ink is vaporized. The bubble jet (registered trademark) method is, similarly to the thermal inkjet method, a method in which the ink is ejected by the energy of the steam explosion at the time when the ink is vaporized. Although the thermal inkjet method differs from the bubble jet (registered trademark) method in the heating region, those methods are based on the same basic principle.

[0018]

In order to form an electrode layer by use of the inkjet method, the ink for forming the electrode layer is prepared. When a positive electrode layer is manufactured, positive electrode ink containing a constituent element of the positive electrode layer is prepared. When a negative electrode layer is manufactured, negative electrode ink containing a constituent element of the negative electrode layer is prepared. For example, the positive electrode ink contains at least the positive electrode active material. In addition, the positive electrode ink may additionally contain a conductive material, a lithium salt, a solvent, and the like. In order to improve ionic conductivity of the positive electrode, the positive electrode ink may contain a polymer electrolyte raw material which becomes the polymer electrolyte by polymerization and a polymerization initiator. It should be noted that a method to form the electrode layer by use of the inkjet method is described later in detail.

[0019]

Then, a substrate forming the electrode layer is prepared. As the substrate, a member neighboring to the electrode layer in the battery, for example, the collector or the polymer electrolyte membrane is used. The

general thickness of the collector ranges from 5 to 20  $\mu\text{m}$ . However, the collector having the thickness out of the range may also be used. The substrate is supplied to the inkjet apparatus which is capable of printing with the electrode ink. Then, the electrode ink is ejected toward the substrate by the inkjet method to have the electrode ink adhered to the substrate. The amount of the ink ejected from the nozzle of the inkjet apparatus is extremely small, and a quantity having a substantially equal volume can be ejected. Accordingly, the electrode layer formed by the adhesion of the ink is very thin and uniform in thickness. Further, if the inkjet method is used, the thickness and the shape of the electrode layer can be precisely controlled. When the electrode layer is formed by use of the conventional coater, it is difficult to form the electrode layer having a complicated shape. On the other hand, if the inkjet method is used, the electrode layer having a desired shape can be formed by designing a predetermined pattern on a computer and only by printing the predetermined pattern thus designed. Also, with regard to the thickness, when the thickness of the electrode layer is not enough by one-time printing, the printing can be repeated twice or more to the same plane. In other words, the printing by the same ink is repeated on the same substrate. This allows formation of the electrode layer having the desired thickness.

[0020]

The thickness of the electrode layer is not particularly limited. Generally, the thickness of the positive electrode layer ranges from about 1 to 100  $\mu\text{m}$ , and the thickness of the negative electrode layer ranges from about 1 to 140  $\mu\text{m}$ .

[0021]

Although the electrode of the present invention can be formed by use of

the inkjet method, the type of the inkjet method is not particularly limited. As described in the embodiment, a necessary improvement may be performed in accordance with the ink used. For the present, the inkjet method is an art very widely known, thus detailed description thereof is omitted.

[0022]

Now, description is made of major advantages brought about by the electrode of the present invention.

[0023]

In the electrode of the present invention, the film thickness of the electrode plane where the electrode layer is laminated is very uniform. Therefore, heat dissipation from the electrode plane becomes uniform and local degradation is suppressed.

[0024]

Further, the battery having the electrode of the present invention has high durability against the vibration. Since the durability against the vibration is high, the battery having the electrode of the present invention is preferably applicable to the use in which the vibration is easily applied, for example, to a vehicle. It is assumed that the durability against the vibration is attributed to the uniformity of the film and the microstructure of the electrode layer produced by the inkjet method. If the uniformity of the film is high, resonance caused by a distribution of the thickness can be reduced. Further, as shown in Fig. 2, the electrode layer produced by the inkjet method is constituted by a number of dots 202 formed by the electrode ink adhered. The dot 202 has a structure in which the dot 202 is connected to the neighboring dot 202 in an interface with the

neighboring dot 202 by plane tension. In such microstructure, the dot 202 acts as a mass and a portion 204 connected by the plane tension acts as a spring, and the microstructure has an action shown as a "mass-spring model." The durability against the vibration is assumed to have been brought about by an action such as the mass-spring model shown. However, a technical scope of the present invention should be determined based on Claims. Even when the mechanism which increases the durability against the vibration is different, the mechanism cannot be beyond the technical scope of the present invention thereby.

[0025]

Further, if the electrode is thin, the energy density of the battery using the electrode is improved. When the battery is applied to the use, such as a power source for a vehicle, in which high output is required, an assembled battery in which a number of batteries are connected is constituted. If a size of the battery is large, the assembled battery having a certain output also becomes large. Since the electrode of the present invention is very thin, it largely contributes to miniaturization of the assembled battery. With reference to the vehicle, the volume of the vehicle is limited, and weight reduction of the assembled battery favorably affects the improvement of fuel economy of the vehicle. Therefore, the miniaturization of the assembled battery is particularly beneficial in a case where the assembled battery is used as the power source for the vehicle.

[0026]

Now, description is made of the thickness and the flatness of the electrode according to the present invention. In the electrode of the present invention, the average thickness of the electrode plane ranges from 5 to 300



μm. By producing the electrode plane by use of the inkjet method, an electrode having such average thickness and being flat can be produced. Here, the electrode plane is defined to be a region where the collector and the electrode layer are laminated. In Fig. 1, a portion where the electrode layer 102 is formed on the collector 104 is correspondent with the electrode plane. When the electrode layer is formed on each of both planes of the collector, the total thickness in which one layer of the collector and two layers of the electrode layer are added is corresponded with the thickness of the electrode plane. In the electrode in which the electrode layer is formed on one plane of the collector, the average thickness of the electrode plane preferably ranges from 6 to 120 μm. In the electrode in which the electrode layers are formed on both planes of the collector, the average thickness of the electrode plane preferably ranges from 7 to 300 μm.

[0027]

Although an area of the electrode plane is not particularly limited, generally, maintenance of the uniformity of the electrode plane becomes more difficult as the area of the electrode plane is widened. From this point of view, the present invention is particularly beneficial when the area of the electrode plane is 50 cm<sup>2</sup> or more.

[0028]

Furthermore, the electrode of the present invention is very flat while having such average thickness, and the maximum thickness of the electrode plane is 105% or less of the minimum thickness of the electrode plane. By having such flatness, unevenness of the heat dissipation can hardly be caused, and lifetime of the battery is elongated. Further, generation of the crack or rupture of the battery which is caused by the resonance caused by the

distribution of the thickness is also suppressed.

[0029]

In the present application, the thickness of the electrode and the thickness of the battery are measured by the following procedure.

[0030]

The thickness of the electrode and the thickness of the battery can be measured by use of a micrometer. The type of the micrometer is not particularly limited, as long as the measurement data having the reliability of a certain level can be obtained.

[0031]

In measuring the average thickness of the electrode plane, the domain to be measured is firstly divided into nine domains of 3x3. Then, the thicknesses at arbitrary three points in each of the domains are measured, and the average thereof is set to the thickness of the domain. The measurement of the thickness is performed of all of the domains to calculate the average thereof. This operation is repeated ten time or more, and the average thereof is set to the average thickness of the electrode plane. It should be noted that, in the present application, the number of repetition of the operation is set to "the repetition number N."

[0032]

The maximum thickness of the electrode plane and the minimum thickness of the electrode plane are measured as the thickness of the domain

where the thickness of the domain is the maximum and the thickness of the domain where the thickness of the domain is the minimum, respectively.

[0033]

The average thickness of the electrode plane located within 10 mm from the uncoated portion which is the portion where the electrode layer is not laminated on the collector divides the domain in the vicinity of the uncoated portion into three portions such that distances from the uncoated portion are equal. In the embodiment as shown in Fig. 1, the electrode layer domain within 10 mm from the interface between the electrode layer 102 and the uncoated portion 104 is divided into three domains such that one side of each of the three domains becomes the interface. Of the respective of the three divided domains, the thickness at arbitrary three points in respective domains is measured, and the average thereof is set to the thickness of the domain. The measurement of the thickness is performed of all of the domains to calculate the average thereof. This operation is repeated ten times or more, and the average thereof is set to the average thickness of the electrode plane within 10 mm from the uncoated portion.

[0034]

When the electrode is adjusted to a predetermined size after the formation of the electrode layer, although the electrode layer is subjected to cutting, the thickness in the vicinity of the cut portion tends to be thinner. Therefore, the thickness in the vicinity of the cut portion may be measured as a barometer of the uniformity of the electrode. In this case, the average thickness of the electrode plane within 10 mm from the cut portion is measured in the same manner as the average thickness of the electrode plane within 10 mm from the uncoated portion.

[0035]

The average thickness of the electrode plane within 10 mm from the region where the electrode layer is not laminated on the collector is preferably 104% or less of the average thickness of the electrode plane in the region other than the region mentioned above. The region where the electrode layer is not laminated on the collector means a domain where the electrode layer is not formed as the uncoated portion 106 or the like in Fig. 1. In the electrode layer formed on the collector, a region in the vicinity of the uncoated portion tends to be thicker. Although the tab tends to be formed on the uncoated portion where the electrode layer is not laminated on the collector, if the portion is thick, the resonance is generated by the vibration applied to the battery, thus there is increasing possibility that the tab and the collector are torn off.

[0036]

Further, preferably, the ratio ( $\sigma/A$ ) of the standard deviation ( $\sigma$ ) of the thickness of the electrode layer to the average thickness ( $A$ ) of the electrode layer is 3% or less. The relationship between the distribution of the thickness and the unevenness of the heat dissipation is already described, and specifically, if the electrode has the flatness of the degree satisfying such value, the unevenness of the heat dissipation is hard to be caused, and the resonance caused by the distribution of the thickness is also hard to be caused. Therefore, the lifetime of the battery is elongated.

[0037]

The high flatness is beneficial particularly when the battery is applied to a vehicle. When the battery is used as the power source for the vehicle, a

number of batteries are laminated in order to secure the large output. When a large number of the batteries are laminated, even a slight difference in the thickness is largely reflected in the thickness of the whole of the assembled battery. In some cases, the battery cannot be fixed. Such problem is solved by the present invention.

[0038]

The electrode of the present invention may be either the positive electrode or the negative electrode. As described above, preferably, the electrode layer is formed by the inkjet method in which the liquid containing the active material is ejected in the form of a number of particles to have the particles adhered to the predetermined substrate. The predetermined substrate is different depending on a manufacturing process. When an electrode layer is formed on a collector, the substrate is the collector. When a polymer electrolyte is used as the electrolyte, the electrode layer is produced on the polymer electrolyte, and then the collector may be arranged.

[0039]

The material which constitutes the electrode, such as the collector, the active material, or the like is not particularly limited in the present application, and known materials can be used, or a newly developed material may also be used. When the electrode of the present invention is the electrode for the lithium battery, Li-Mn based composite oxide such as  $\text{LiMn}_2\text{O}_4$ , or the like, or Li-Ni based composite oxide such as  $\text{LiNiO}_2$  or the like can be cited as the positive electrode active material. In some cases, two or more kinds of the positive electrode active material may be used at the same time. A crystalline carbon material or a non-crystalline carbon material can be cited as the negative electrode active material. Specifically, natural graphite, synthetic graphite,

carbon black, activated carbon, carbon fiber, cokes, soft carbon, hard carbon, or the like can be cited. In some cases, two or more kinds of the negative electrode active material may also be used at the same time.

[0040]

The constitution of the electrode layer is not particularly limited and can be properly selected in accordance with the application. When the electrode of the present invention is a positive electrode, at least a positive electrode active material is contained in the positive electrode layer. In addition, a conductive material, a lithium salt, or the like may be contained in the positive electrode layer. In order to improve the ionic conductivity of the positive electrode, the polymer electrolyte may have been dispersed. The compounding quantities of these materials are not particularly limited, and the compounding quantity may be determined based on the knowledge already obtained.

[0041]

A second aspect of the present invention is a battery formed by use of the electrode. The electrode may be either the positive electrode or the negative electrode. At least one of the positive electrode or the negative electrode is used. Preferably, both of the positive electrode and the negative electrode are the electrodes of the present invention.

[0042]

Since the electrode has the uniform thickness, a battery having the uniform thickness is obtained. The battery of the present invention is preferably a rectangular battery formed by containing a battery constituting element composed of a positive electrode and a negative electrode in an exterior

packaging material composed of a polymer metal composite film, and the average thickness of the portion, where the battery constituting element is stored, within 10 mm from the end of the portion where the battery constituting element is stored is 104% or less of the average thickness of the battery in the portion, where the battery constituting element is stored, exceeding 10 mm from the end where the battery constituting element is stored.

[0043]

Here, "the battery constituting element" means an element in which the positive electrode, the negative electrode, and, in some cases, a solid electrolyte membrane are laminated and a power generating reaction actually progresses. When the battery constituting element is stored in the polymer metal composite film, the battery constituting element is stored inside of the exterior packaging material in a form that a tab is drawn to the outside of the exterior packaging material. Then, in order to secure sealing characteristics of the inside, the polymer metal composite film of the portion where the battery constituting element is not stored is sealed. Accordingly, the thickness of the portion where the battery constituting element is stored is the substantial thickness of the battery. When the battery of the present invention takes such mode, it is preferable that the thickness of the portion where the battery constituting element is stored satisfies the requirement described above. In other words, preferably, the average thickness of the portion where the battery constituting element is stored within 10 mm from the end of the portion where the battery constituting element is stored is 104% or less of the average thickness of the battery in the portion, where the battery constituting element is stored, which is 10 mm or more away from the end of the portion where the battery constituting element is stored. "The end of the portion where the battery constituting element is stored" means a boundary with respect to the substantial thickness of the battery. In other words, it means a portion where the thickness of the

battery commences to be steeply thinned. If a battery having the superior flatness of 104% or less of the thickness in the vicinity of the boundary, in comparison with the thickness of the portion which is not in the vicinity of the boundary, the battery can easily be laminated. It should be noted that the thickness of the battery can be measured in accordance with the method of measuring the thickness of the electrode. Normally, "the end of the portion where the battery constituting element is stored" exists in four sides. In this case, the average thickness may be measured of each of the sides for the purpose of the measurement of the average.

[0044]

The polymer metal composite film is a film on which at least a metal foil film and a resin film are laminated. By use of such exterior packaging material, a thin laminated battery is formed. In the laminated battery having the flatness of the range described above, deterioration of the battery characteristics due to the vibration applied to the battery is hard to be caused.

[0045]

In a general battery, the positive electrode, the electrolyte, and the negative electrode are arranged in this sequence and they are sealed in the exterior packaging material. The electrolyte may be either solid or liquid. Further, the exterior packaging material is not particularly limited. If application to a vehicle is considered, the electrolyte is preferably solid. Further, the battery is preferably a lithium secondary battery.

[0046]

For reference, shown in Fig. 3 are the thickness distributions of the



lithium secondary battery having the positive electrode and the negative electrode of the present invention and the lithium secondary battery having the positive electrode and the negative electrode which are manufactured by use of a conventional coater. As shown in Fig. 3, in the conventional type battery, the thickness of the battery is steeply increased in the vicinity of the uncoated portion which is used for the connection with the tab. On the other hand, in the battery of the present invention, the thickness of the battery is maintained even in the vicinity of the uncoated portion which is used for the connection with the tab.

[0047]

The batteries of the present invention may be connected in series, in parallel, or in series and in parallel combined to constitute an assembled battery. Fig. 4A is a plan view, Fig. 4B is a front view, and Fig. 4C is a side view of the assembled battery. The assembled battery is mounted in an exterior packaging case 402. A terminal 404 is drawn out from the exterior packaging case 402 to be used for the connection with another apparatus. It should be noted that, in order to clearly show the installment state of the assembled battery, Figs. 4A to 4C are drawn as perspective diagrams.

[0048]

Each of respective assembled batteries may be further connected in series, in parallel, or in series and in parallel combined, to form multiple assembled batteries. Fig. 5A is a plan view, Fig. 5B is a front view, and Fig. 5C is a side view of the multiple assembled batteries. An assembled battery 502 is fixed by use of a connection plate 504 and a connection screw 506, and connected in series or in parallel. Between each of the assembled batteries 502 and at the lowermost portion thereof, outer elastic members 508 are

arranged for buffering shocks applied from the outside.

[0049]

The number and the way of connection of the batteries in the assembled battery and the multiple assembled batteries may be determined in accordance with the output and the capacity required for the battery. When the assembled battery or the multiple assembled batteries is formed, the stability as the battery is increased in comparison with a single battery. The influence of the degradation of one cell on the whole battery can be reduced by constituting the assembled battery or the multiple assembled batteries.

[0050]

The assembled battery or the multiple assembled batteries can be preferably used for a vehicle. Fig. 6 is a side schematic view of a vehicle to which the assembled battery or the multiple assembled batteries 602 of the present invention is loaded. The assembled battery or the multiple assembled batteries 602 to be loaded on the vehicle have the characteristics described above. Therefore, the vehicle in which the battery of the present invention is loaded has the high durability and can provide the sufficient output even after it is used for a long period of time. Further, since the occupied volume of the battery is small, the space inside the vehicle is widened.

[0051]

The battery of the present invention is particularly beneficial when it is used for a vehicle. Conventionally, when the battery is used for the vehicle, it is necessary to laminate a number of batteries, and the difference in the thickness of the battery is emphasized, which results in a problem that the fixing of the

battery to the vehicle is difficult. The problem is now solved by use of the flat battery of the present invention, which also has high durability against the vibration, thus the battery degradation caused by the resonance is hard to be caused, even if the battery is used in an environment like the vehicle where the vibration is constantly applied.

[0052]

The battery being small in size also has a great advantage when it is applied to a vehicle. It is assumed, for example, that a bipolar battery, of which electrode and polymer electrolyte are manufactured by the inkjet method, is formed. In this case, it is also assumed that the thickness of the collector is 5  $\mu\text{m}$ , the thickness of the positive electrode layer is 5  $\mu\text{m}$ , the thickness of the solid electrolyte layer is 5  $\mu\text{m}$ , the thickness of the negative electrode layer is 5  $\mu\text{m}$ , and the thickness of one battery element is 20  $\mu\text{m}$ . If one hundred layers of such are laminated to manufacture a bipolar battery having the output of 420 V, the bipolar battery has the output of 25 kW and 70 Wh with the battery volume of 0.5 liter. Theoretically, the same output as the conventional battery can be taken out by the battery having the size of less than 1/10.

[0053]

A third aspect of the present invention relates to a manufacturing method of an electrode. Namely, the third aspect of the present invention is the method of manufacturing the electrode including a process of forming an electrode layer by use of the inkjet method in which a liquid containing an active material is ejected as a number of particles to a predetermined substrate to have the particles adhered to the substrate.

[0054]

If the electrode layer is formed by use of the inkjet method, as described above, a thin electrode layer which is also uniform in thickness can be manufactured. Since the effect held by the electrode layer itself formed by use of the inkjet method has already been described in the first aspect of the present invention, the description thereof is omitted here.

[0055]

As an advantage as the method when the electrode layer is formed by use of the inkjet method, the improvement of workability can be cited. In the conventional method in which the electrode layer is formed by use of the coater such as the roller coater, it is essential that separate coaters exist respectively for the positive electrode and the negative electrode, thus a large-scale manufacturing line has to be made, and the manufacturing time of the electrode is longer. However, if the method in which the electrode layer is formed by use of the inkjet method of the present invention is adopted, the positive electrode layer and the negative electrode layer, and in some cases, the polymer electrolyte membrane can be produced by a single inkjet line. Further, contrary from the conventional method, an electrode layer of a precise pattern can be produced. Furthermore, a design can be freely changed on the computer. Accordingly, the use of the method of the present invention can produce a plurality of kinds of the electrode layer and polymer electrolyte membrane by use of only one set of the inkjet line.

[0056]

In order to manufacture the electrode by use of the method of the present invention, the substrate where the electrode layer is formed by use of the inkjet method is firstly prepared. As the substrate, the collector or the

polymer electrolyte membrane may be used. When the substrate is difficult to be singly supplied to the inkjet apparatus, may be used is the method in which the substrate is pasted on a medium such as a paper or the like and the medium is supplied to the inkjet apparatus.

[0057]

Prior to the printing by the inkjet method, the positive electrode ink and the negative electrode ink are prepared. When the polymer electrolyte membrane is also produced by the inkjet method, the electrolyte ink is also prepared.

[0058]

As components contained in the positive electrode ink, the positive electrode active material, the conductive material, the polymer electrolyte raw material, the lithium salt, the polymerization initiator, and the solvent are cited, and at least the positive electrode active material is contained therein. The positive electrode ink may be made to contain the polymer electrolyte raw material such as a macro-monomer with ethylene oxide and propylene oxide, or the like and the polymerization initiator such as benzyldimethylketal, or the like for the printing of the positive electrode layer, and thereafter they are polymerized to improve the ionic conductivity of the electrode layer. These components are added in the solvent to be well agitated. Although the solvent is not particularly limited, acetonitrile may be cited, for example.

[0059]

A compounding ratio of the components contained in the positive electrode ink is not particularly limited. However, the viscosity of the positive

electrode ink should be enough low in the degree at which the inkjet method is applicable. As the method of keeping the viscosity in the low level, a method of increasing the compounding quantity of the solvent, and a method of increasing the temperature of the positive electrode ink can be cited. However, if the compounding quantity of the solvent is excessively increased, the amount of active material per unit volume in the electrode layer is decreased, thus the compounding quantity of the solvent may be suppressed to the minimum. The polymer electrolyte raw material or other compounds may be improved such that the viscosity is lowered.

[0060]

As the components contained in the negative electrode ink, the negative electrode active material, the conductive material, the polymer electrolyte raw material, the lithium salt, the polymerization initiator, and the solvent can be cited, and at least the negative electrode active material is contained therein. The negative electrode ink may be made to contain the polymer electrolyte raw material such as the macro-monomer with ethylene oxide and propylene oxide, or the like, and the polymerization initiator such as benzyldimethylketal, or the like, for printing the negative electrode layer, and thereafter they are polymerized to improve the ionic conductivity of the electrode layer. These components are added in the solvent to be well agitated. Although the solvent is not particularly limited, acetonitrile may be cited, for example.

[0061]

The compounding ratio of the components contained in the negative electrode ink is not particularly limited. Since the description of the compounding ratio is the same as in the description regarding the positive electrode ink, it is omitted here.

[0062]

As the components contained in the electrolyte ink, the polymer electrolyte raw material, the lithium salt, the polymerization initiator, and the solvent can be cited, and at least the polymer electrolyte raw material is contained therein. As the polymer electrolyte raw material, there is no specific limitation as long as the compound can form the polymer electrolyte layer by the polymerization after performing the inkjet method. For example, the macro-monomer with ethylene oxide and propylene oxide may be cited. These components are added in the solvent to be well agitated. Although the solvent is not particularly limited, acetonitrile may be cited, for example.

[0063]

The compounding ratio of the components contained in the electrolyte ink is not particularly limited. Since the description of the compounding ratio is the same as in the description of the positive electrode ink, it is omitted here. Since the electrolyte ink contains a relatively large amount of polymer electrolyte raw material, which is easy to increase the viscosity of the ink, attention should be paid to this point. It should be noted that it goes without saying that, if the electrolyte contained in the battery produced is liquid, the electrolyte ink is not required.

[0064]

Although the viscosity of respective inks supplied to the inkjet apparatus is not particularly limited, it is preferably in the range of 0.1 to 50 cP.

[0065]

The ink is ejected to the substrate by use of the inkjet method to form the electrode layer. When the electrode layer is formed, the pattern of the electrode layer is previously determined. If the electrode layer is made to be formed based on an image produced on a computer, the excellent workability is obtained. The pattern determination and the formation of the electrode layer by use of the computer are the same as the generally well-known operations of the image formation and the printing-out by use of the computer and printer. Accordingly, it can be said that the realization of the present invention in the industrial production is comparatively easy in the point that the developed knowledge can be applied in the field.

[0066]

The collector is supplied to the inkjet apparatus, the electrode ink which is the liquid containing the active material is ejected in the form of a number of particles, and the particles are adhered to the substrate in accordance with the pattern previously designed. An ink ejection mechanism to be adopted by the inkjet apparatus may be any one of the piezoelectric method, the thermal inkjet method, and the bubble jet (registered trademark) method. Preferably used is the piezoelectric method in which the ink particles are ejected by the change in the volume of the piezoelectric elements.

[0067]

The volume of the particles ejected from the inkjet apparatus is preferably within a range from 1 to 100 picoliters. If the volume of the ejected particles is too small, there is a possibility that the vibration reduction is insufficient. On the other hand, if the volume of the ejected particles is too much, there is also a possibility that the vibration reduction is insufficient. The



volume of the particles ejected by use of the inkjet apparatus is substantially the same, and the electrodes and batteries manufactured have a very high uniformity in the thickness.

[0068]

When the film thickness of the electrode layer formed by adhering the particles only once by the inkjet apparatus is insufficient, the particles may be adhered to the same location twice or more to increase the thickness of the electrode layer. "The same location" means a portion which is the same as the portion where the electrode layer is formed by the first-time printing by the inkjet apparatus. In other words, it is over-coating with the same material. The thickness of the electrode can be increased by laminating the electrode layer of the uniform thickness by use of such a manner. When the electrode layer is formed by use of the inkjet method, the uniformity of the thickness of the electrode layer formed is very high, thus the high uniformity is maintained, even if the lamination is made a number of times.

[0069]

After the electrode layer is formed, the solvent is removed by drying. If the polymer electrolyte raw material is compounded, in order to form the polymer electrolyte by the polymerization, the polymerization processing may be performed. For example, when the photo-polymerization initiator is added, for example, ultraviolet ray is irradiated to commence the polymerization, thereby the electrode is completed.

[0070]

The process to which the method of manufacturing the electrode of the

present invention is applied is different depending on the battery finally manufactured. For example, when producing the lithium ion battery which is formed by interposing the liquid electrolyte in the positive electrode and the negative electrode, and by sealing them in the exterior packaging material, the positive electrode and the negative electrode are respectively manufactured according to the present invention, and then a battery can be assembled by use of them. When a totally solid bipolar battery is produced, a collector is used as the substrate, a positive electrode layer, a polymer electrolyte membrane, and a negative electrode layer are sequentially produced by use of the inkjet method, thus the collector is laminated. The totally solid bipolar battery having a number of laminated layers is completed by repeating the operation depending on the necessity. In this case, the present invention is applied to the production of the positive electrode layer, the polymer electrolyte membrane, and the negative electrode layer.

[0071]

It should be noted that, in an industrial production process, in order to improve the productivity, a process may be adopted in which an electrode which is larger than the size of the final battery is firstly produced and then the electrode is cut into a predetermined size.

[0072]

A fourth aspect of the present invention provides another method of manufacturing a battery. In other words, the fourth aspect of the present invention provides a method of manufacturing the battery including a process of forming a negative electrode layer by use of the inkjet method in which a liquid containing a negative electrode active material is ejected in a form of a number of particles, and a process of forming a positive electrode layer by use of the

inkjet method in which a liquid containing a positive electrode active material is ejected in a form of a number of particles.

[0073]

So long as the positive electrode layer and the negative electrode layer are manufactured by use of the inkjet method, there is no specific limitation in the working sequence. The negative electrode layer may be formed after the positive electrode layer is formed, or the positive electrode layer may be formed after the negative electrode layer is formed. Respective of the positive electrode layer and the negative electrode layer may be entirely separately formed to be made opposed each other via the electrolyte in the battery assembling stage.

[0074]

The method of manufacturing the battery according to the present invention may also include a process of forming the polymer electrolyte membrane by use of the inkjet method in which a liquid containing the polymerization initiator and the polymer electrolyte raw material forming the polymer electrolyte by the polymerization reaction induced by the polymerization initiator is ejected as a number of particles. Of the polymerization initiator and the polymer electrolyte raw material, descriptions have already been made, thus it is omitted here.

[0075]

The method of manufacturing the battery according to the present invention is characterized in that the positive electrode layer, the negative electrode layer, and the polymer electrolyte membrane as necessary, are

manufactured by use of the inkjet method. Since practical conditions and constituting materials necessary for the manufacture thereof have already been described in the descriptions of the first to third aspects of the present invention, descriptions thereof are omitted here. It goes without saying that the related well-known knowledge may also be suitably referred.

[0076]

[EMBODIMENT]

Hereinafter, description is made of the present invention further in detail by an embodiment. In the following embodiment, unless otherwise described, the macro-monomer with ethylene oxide and propylene oxide is used as the polymer electrolyte raw material,  $\text{LiN}(\text{SO}_2\text{C}_2\text{F}_5)_2$  (hereinafter referred to as BETI) is used as the lithium salt, spinel type  $\text{LiMn}_2\text{O}_4$  (average particle diameter being  $0.6\ \mu\text{m}$ ) is used as the positive electrode active material, the ground graphite (average particle diameter being  $0.7\ \mu\text{m}$ ) is used as the negative electrode active material, and benzyldimethylketal is used as the photo-polymerization initiator.

The polymer electrolyte raw material is synthesized in accordance with the method disclosed in Japanese Patent Application Laid-Open No. 2002-110239. Further, the preparation and printing of the negative electrode ink, the positive electrode ink, and the electrolyte ink, and the assembly of the battery are performed under a dry atmosphere at the temperature of  $30^\circ\text{C}$  below zero.

[0077]

[EMBODIMENT 1]

The positive electrode active material (7% by bass), acetylene black as

the conductive material (2% by mass), the polymer electrolyte raw material (4% by mass), the lithium salt (2% by mass), and the photo-polymerization initiator (0.1% by mass to the polymer electrolyte raw material) are prepared, and acetonitrile (85% by mass) is added thereto as the solvent. Then, mixture of these is subjected to sufficient agitation to prepare slurry as the positive electrode ink. The viscosity of the ink is about 3 cP.

[0078]

The prepared ink and the commercially available inkjet printer are used to produce the positive electrode by the following procedure. It should be noted that, when the ink described above is used, there is a problem that the acetonitrile being the solvent dissolves a plastic part located at the ink introducing portion of the inkjet printer. Therefore, the part located at the ink introducing portion is replaced with a metal part, and the ink is made to be directly supplied to the metal part from an ink chamber. Further, the viscosity of the ink is low and there is an anxiety that the active material is precipitated, so the ink chamber is made to be constantly agitated by use of a rotary vane.

[0079]

The inkjet printer is controlled by a commercially available computer and soft wear. The prepared positive electrode ink is used in producing the positive electrode layer. The positive electrode layer is produced in such a manner that a pattern produced on the computer is printed by use of the inkjet printer. It should be noted that, since it is difficult to directly supply a metal foil to the printer, the metal foil is pasted to a good quality paper of A4 plate size, and the paper is supplied to the printer to be printed.

[0080]

The positive electrode ink is introduced into the inkjet printer subjected to the modification described above, and the pattern produced on the computer is printed on an aluminum foil having the thickness of 20  $\mu\text{m}$  as the collector. The volume of the particles of the positive electrode ink, which is ejected from the inkjet printer, is about 2 picoliters. The positive electrode layer is formed by printing the positive electrode ink on the same plane five times.

[0081]

After the printing, two-hour drying is performed at 60°C in a vacuum oven in order to dry the solvent. After the drying, in order to polymerize the polymer electrolyte raw material, an ultraviolet ray is irradiated for 20 minutes in the vacuum, thus the positive electrode layer is laminated on the collector.

[0082]

The same operation is also performed to the plane where the positive electrode layer of the collector is not formed, thus the positive electrode having the positive electrode layers formed on both planes of the collector is obtained. Thereafter, the positive electrode is cut so as to be in the predetermined battery size.

[0083]

The thickness of the positive electrode is examined. The average thickness of the electrode plane where the collector and the electrode layer are laminated is about 126  $\mu\text{m}$ . It should be noted the average thickness of the electrode plane is the total sum of the aluminum foil (20  $\mu$ ) and the electrode layers (53  $\mu\text{m}$ ) formed on the both planes of the aluminum foil. A location

where the electrode plane where the collector and the positive electrode layers are laminated is the thinnest is in the vicinity of the cut portion of the electrode. On the other hand, a location where the electrode plane is the thickest is in the vicinity of "the uncoated portion" which is the portion where the electrode layer is not laminated on the collector. The maximum value of the thickness is 100.1% of the minimum value of the thickness. In other words, a very flat electrode is obtained. The ratio of the average thickness of the electrode plane within 10 mm from the uncoated portion where the electrode layer is not laminated on the collector for the purpose of connecting the tab to the average thickness of the electrode plane in region other than the region mentioned above is 100.0%. Further, the ratio ( $\sigma/A$ ) of the standard deviation ( $\sigma$ ) of the thickness of the electrode layer to the average thickness ( $A$ ) of the electrode layer is 0.71%.

[0084]

The vibration absorbing ability of the battery which uses the positive electrode is estimated by the following method. An acceleration pickup is set in substantially the central portion of the battery obtained, and a vibration spectrum of the acceleration pickup at the time of hammering by an impulse hammer is measured. The setting method is pursuant to JIS B 0908 (calibration method-fundamental concept of vibration and shock pick-up). The measured spectrum is analyzed by an FFT analyzer to convert into the dimensions of frequency and acceleration. Averaging and smoothing are performed of the obtained frequency to obtain a vibration transmission rate spectrum. Fig. 7 is the vibration transmission rate spectrum. A rate in which an area ratio of a first peak in the acceleration spectrum which is the vibration transmission rate spectrum is shown against the reference is made as the average attenuation rate. This means that the larger is the numerical value the vibration is the more reduced. By using the battery by use of the positive electrode of Comparative Example 1, which is later described, as the reference, the attenuation rate

reduction effect obtained is 45%. The results are summarized and shown in Table 1.

[0085]

It should be noted that, in the embodiment, the measurement of the thickness is performed in accordance with the method described in the Detailed Description of the Invention. The repetition number N for calculating the average is set to 50 times.

[0086]

[EMBODIMENT 2]

The negative electrode active material (9% by mass), the polymer electrolyte raw material (4% by mass), the lithium salt (2% by mass), and the photo-polymerization initiator (0.1% by mass to the polymer electrolyte raw material) are prepared, and acetonitrile (85% by mass) is added thereto as the solvent. Then, mixture of these is subjected to sufficient agitation to prepare slurry as the negative electrode ink. The viscosity of the ink is about 3 cP.

[0087]

The negative electrode ink is introduced into the inkjet printer same as Embodiment 1, to print the pattern produced on the computer onto the copper foil having the thickness of 15  $\mu\text{m}$  being the collector. The volume of the particles of the negative electrode ink, which is ejected from the inkjet printer, is about 2 picoliters. A negative electrode layer is formed by printing the negative electrode ink on the same plane five times.

[0088]



After the printing, drying is performed for two hours in a vacuum oven at 60°C in order to dry the solvent. After the drying, in order to polymerize the polymer electrolyte raw material, an ultraviolet ray is irradiated for 20 minutes in the vacuum, thus the positive electrode layer is laminated on the collector.

[0089]

The same operation is performed also onto a plane where the negative electrode layer of the collector is not formed, thus the negative electrode in which the negative electrode layers are formed on both planes of the collector is obtained. Thereafter, the negative electrode is cut so as to be a predetermined battery size.

[0090]

The thickness of the negative electrode is examined. The average thickness of the electrode plane where the collector and the negative electrode layer are laminated is about 122  $\mu\text{m}$ . It should be noted that the average thickness of the electrode plane is the total sum of the copper foil (15  $\mu\text{m}$ ) and the electrode layers (53.5  $\mu\text{m}$ ) formed on both planes of the copper foil. The location where the electrode plane where the collector and the negative electrode layer are laminated is the thinnest is in the vicinity of the cut portion of the electrode. On the other hand, the location where the electrode plane is the thickest is in the vicinity of "the uncoated portion" which is a portion where the electrode layer is not laminated on the collector. The maximum value of the thickness is 100.1% of the minimum value of the thickness. In other words, an extremely flat electrode is obtained. The ratio of the average thickness of the electrode plane within 10 mm from the uncoated portion where the electrode layer is not laminated on the collector for the purpose of connecting the tab to the

average thickness of the electrode plane in the region other than the region mentioned above is 100.0%. Further, the ratio ( $\sigma/A$ ) of the standard deviation ( $\sigma$ ) of the thickness of the electrode layer to the average thickness (A) of the electrode layer is 0.57%.

[0091]

The vibration absorbing ability of the battery by use of the negative electrode is estimated in the same manner as in Embodiment 1. Using the battery by use of the negative electrode of Comparative Example 2, which is later described, as the reference, the attenuation rate reduction effect of 40% is obtained. The results thereof are shown in Table 1.

[0092]

[COMPARATIVE EXAMPLE 1]

The positive electrode active material (7% by mass), acetylene black (2% by mass) as the conductive material, the polymer electrolyte raw material (4% by mass), the lithium salt (2% by mass), and the photo-polymerization initiator (0.1% by mass to the polymer electrolyte raw material) are prepared, and acetonitrile (85% by mass) is added thereto as the solvent. Then, mixture of these is subjected to sufficient agitation to prepare slurry for the positive electrode layer.

[0093]

The slurry for the positive electrode layer is coated onto an aluminum foil having the thickness of 20  $\mu\text{m}$  as the collector by use of a roller type coater. After the coating, drying is performed for two hours in the vacuum oven at 60°C in order to dry the solvent. After the drying, in order to polymerize the polymer

electrolyte raw material, the ultraviolet ray is irradiated for 20 minutes in the vacuum, thus the positive electrode layer is laminated on the collector.

[0094]

The same operation is performed also onto the plane where the positive electrode layer of the collector is not formed, thereby the positive electrode having the positive electrode layers formed on both planes of the collector is obtained. Thereafter, the positive electrode is cut so as to be the size of the predetermined battery size.

[0095]

The thickness of the positive electrode is examined. The average thickness of the electrode plane where the collector and the positive electrode layer are laminated is about 129  $\mu\text{m}$ . The location where the electrode plane where the collector and the positive electrode layer are laminated is the thinnest is in the vicinity of the cut portion of the electrode. On the other hand, the location where the electrode plane is the thickest is in the vicinity of "the uncoated portion" which is a portion where the electrode layer is not laminated on the collector. The maximum value of the thickness is 106.3% of the minimum value of the thickness. In other words, an electrode whose thickness is greater in the vicinity of the uncoated portion is obtained. The ratio of the average thickness of the electrode plane within 10 mm from the uncoated portion where the electrode layer is not laminated on the collector for the purpose of connecting the tab to the average thickness of the electrode plane in region other than the region mentioned above is 104.1%. Further, the ratio ( $\sigma/A$ ) of the standard deviation ( $\sigma$ ) of the thickness of the electrode layer to the average thickness ( $A$ ) of the electrode layer is 3.1%.

[0096]

[COMPARATIVE EXAMPLE 2]

The negative electrode active material (9% by mass), the polymer electrolyte raw material (4% by mass), the lithium salt (2% by mass), and the photo-polymerization initiator (0.1% by mass to the polymer electrolyte raw material) are prepared, and acetonitrile (85% by mass) is added thereto as the solvent. Then, mixture of these is subjected to the sufficient agitation to prepare slurry for the negative electrode layer.

[0097]

The slurry for the negative electrode layer is coated onto the copper foil having the thickness of 15  $\mu\text{m}$  as the collector by use of the roller type coater. After the coating, the drying is performed for two hours in the vacuum oven at 60°C in order to dry the solvent. After the drying, in order to polymerize the polymer electrolyte raw material, the ultraviolet ray is irradiated for 20 minutes in the vacuum, thereby the negative electrode layer is laminated on the collector.

[0098]

The same operation is performed also to the plane where the negative electrode layer of the collector is not formed, thus the negative electrode having the negative electrode layers formed on both planes of the collector is obtained. Thereafter, the negative electrode is cut so as to be the size of the predetermined battery size.

[0099]

The thickness of the negative electrode is examined. The average

thickness of the electrode plane where the collector and the negative electrode layer are laminated is about 124  $\mu\text{m}$ . The location where the electrode plane where the collector and the negative electrode layer are laminated is the thinnest is in the vicinity of the cut portion of the electrode. On the other hand, the location where the electrode plane is the thickest is in the vicinity of "the uncoated portion" which is a portion where the electrode layer is not laminated on the collector. The maximum value of the thickness is 107.0% of the minimum value of the thickness. In other words, an electrode of which thickness is greater in the vicinity of the uncoated portion is obtained. The ratio of the average thickness of the electrode plane within 10 mm from the uncoated portion where the electrode layer is not laminated on the collector for the purpose of connecting the tab to the average thickness of the electrode plane in region other than the region mentioned above is 104.4%. Further, the ratio ( $\sigma/A$ ) of the standard deviation ( $\sigma$ ) of the thickness of the electrode layer to the average thickness ( $A$ ) of the electrode layer is 3.2%.

[0100]

Table 1

	Average thickness of electrode plane ( $\mu\text{m}$ )	Maximum thickness of electrode plane divided by Minimum thickness of electrode plane	Attenuation rate reduction effect
Embodiment 1	126.2	100.1%	45%
Embodiment 2	122.0	100.1%	40%
Comparative			
Example 1	128.8	106.3%	Reference
Comparative			
Example 2	124.4	107.0%	Reference

[0101]

As shown in Table 1, the electrode of the present invention has extremely high flatness and is superior in the attenuation rate reduction effect, thus contributes to elongation of the lifetime of the battery. Further, since the electrode which is thin and uniform in thickness can be formed, a compact power source having the high output can be achieved.

#### [BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 is a schematic view of an embodiment of an electrode according to the present invention.

Figs. 2A, 2B, 2C are schematic views for describing micro-structures of the electrode according to the present invention.

Fig. 3 is a graph showing thickness distributions of a lithium secondary battery having a positive electrode and a negative electrode according to the present invention and the lithium secondary battery having the positive electrode and the negative electrode manufactured by use of a conventional coater.

Fig. 4A is a plan view, Fig. 4B is a front view, and Fig. 4C is a side view of an assembled battery.

Fig. 5A is a plan view, Fig. 5B is a front view, and Fig. 5C is a side view of multiple assembled batteries.

Fig. 6 is a schematic side view of a vehicle having the assembled battery or the multiple assembled batteries loaded thereon.

Fig. 7 shows spectrums of vibration transmission ratios.

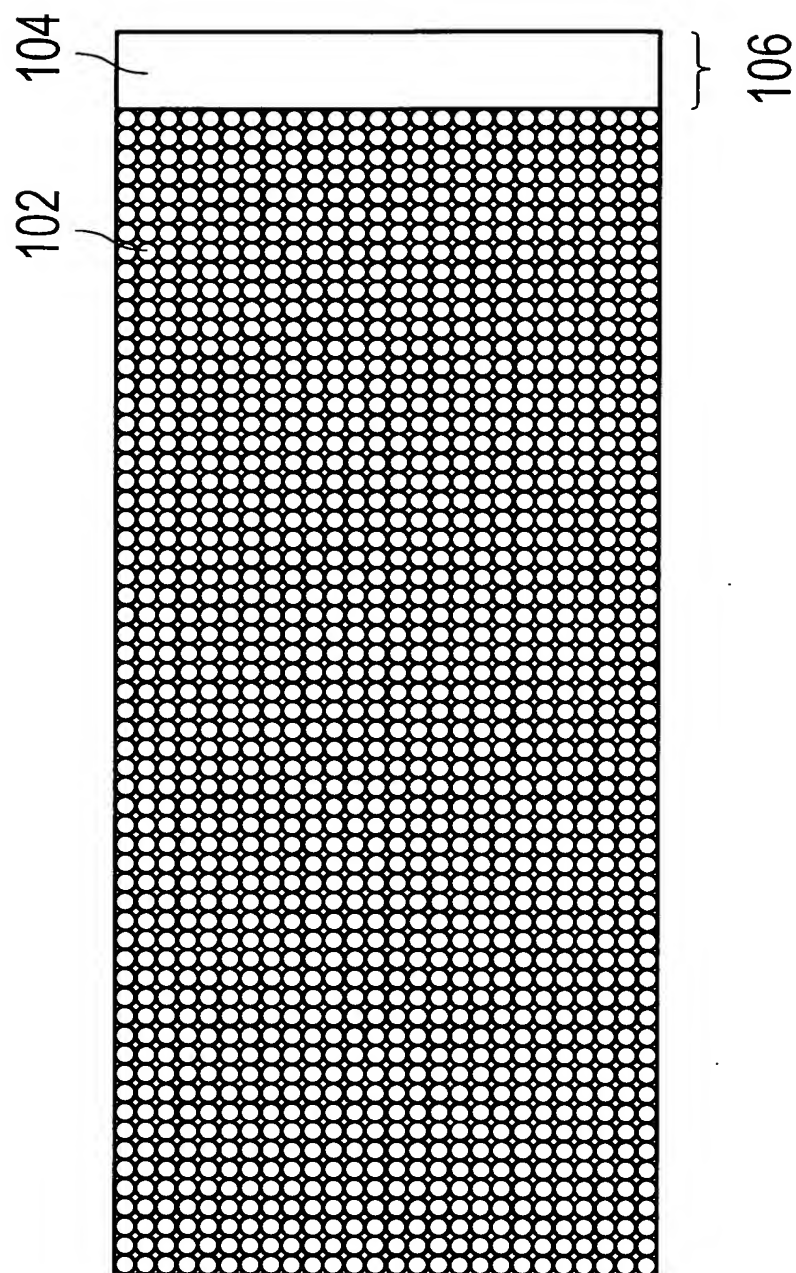
[DESCRIPTION OF CODES]

102	Electrode layer
104	Collector
106	Portion where electrode layer is not laminated (uncoated portion)
202	Dot
204	Portion connected by plane tension
402	Exterior packaging case
404	Terminal
502	Assembled battery
504	Coupling plate
506	Coupling screw
508	External elastic body
602	Multiple assembled batteries

[DOCUMENT TITLE]    DRAWING

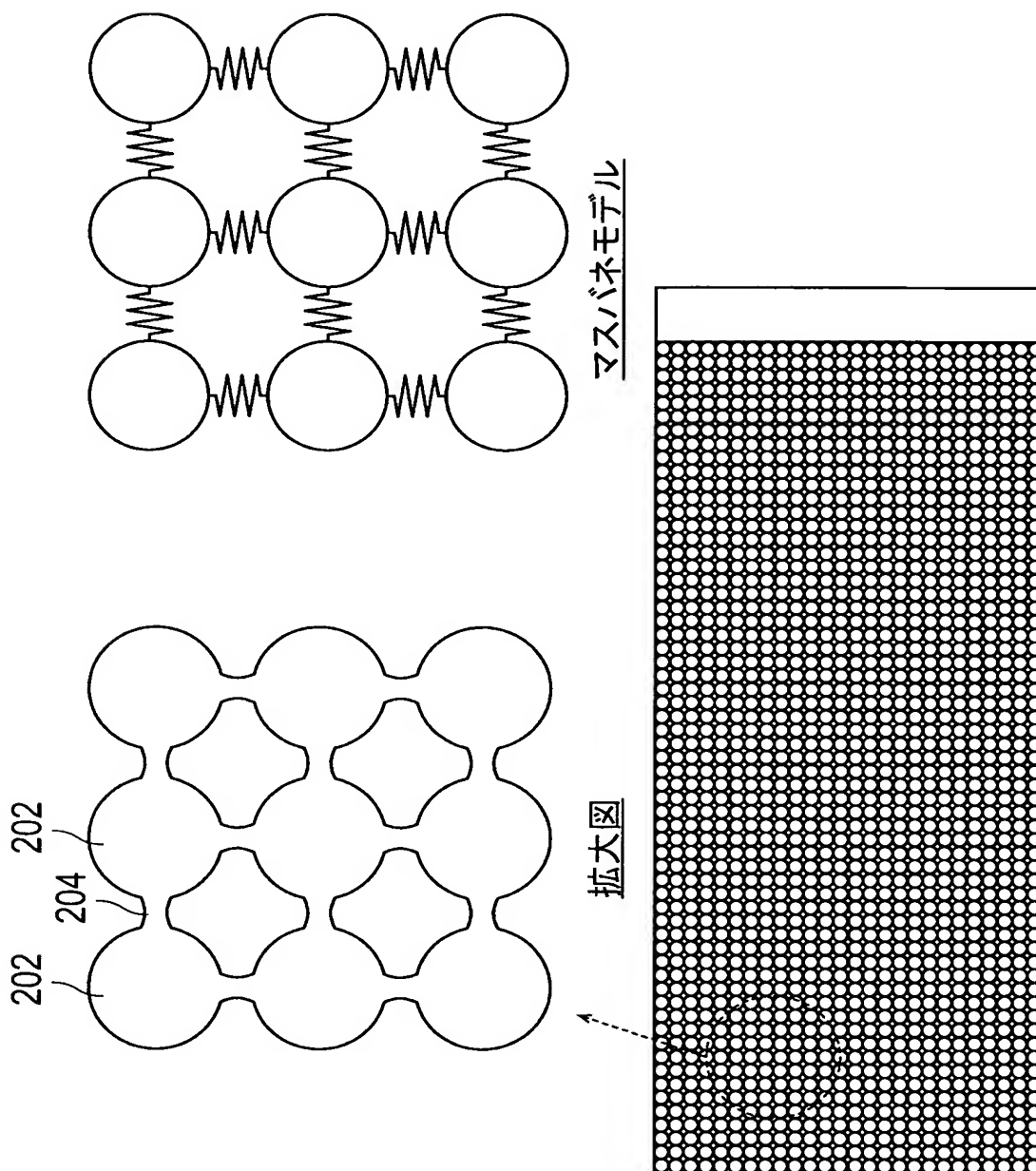
[TECHNICAL POINT]

[FIG. 1]



[FIG. 2]  
EXPANDED VIEW  
MASS SPRING MODEL





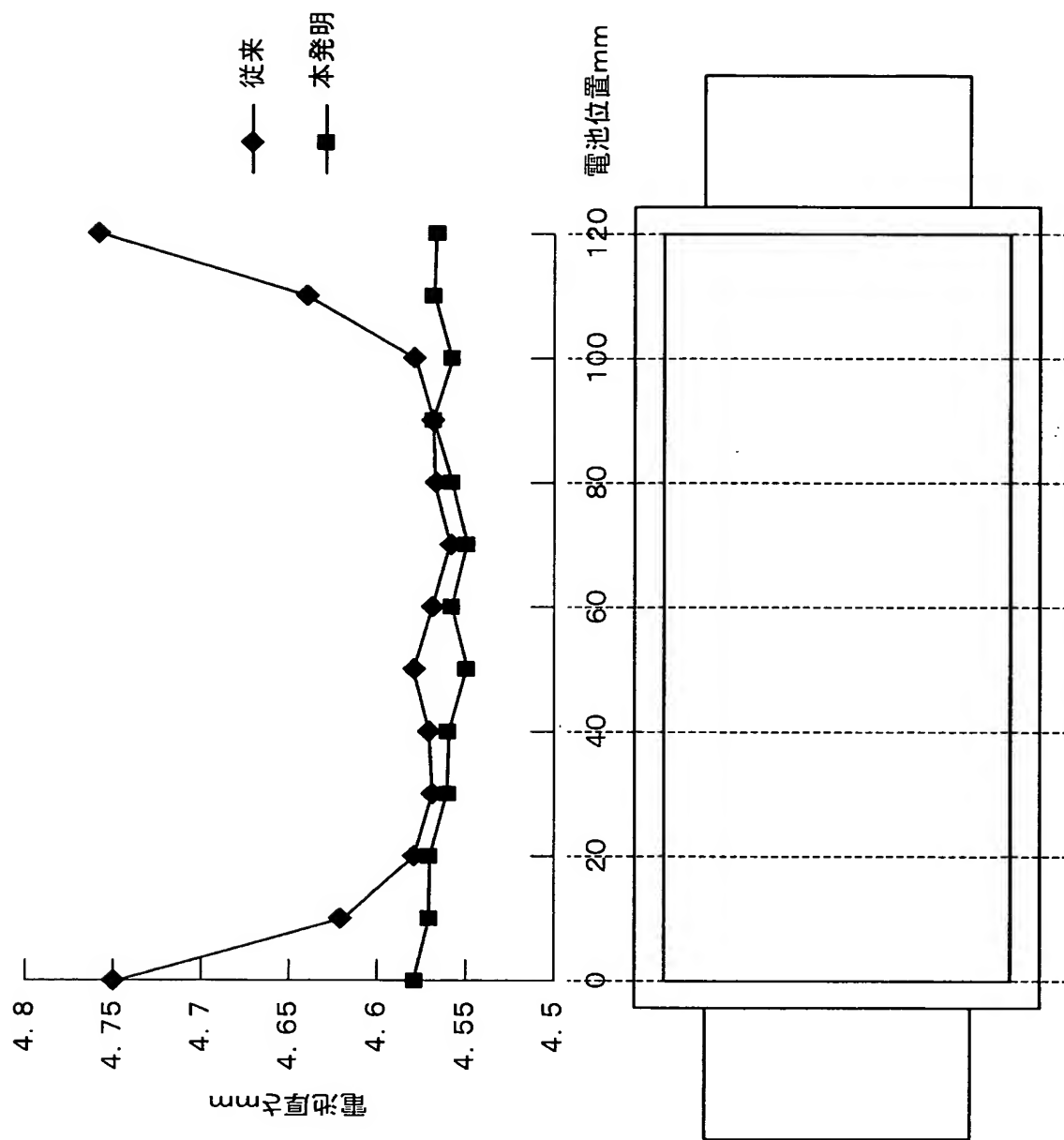
[FIG. 3]

BATTERY OF CONVENTIONAL TECHNOLOGY

BATTERY OF PRESENT INVENTION

BATTERY THICKNESS mm

BATTERY POSITION mm

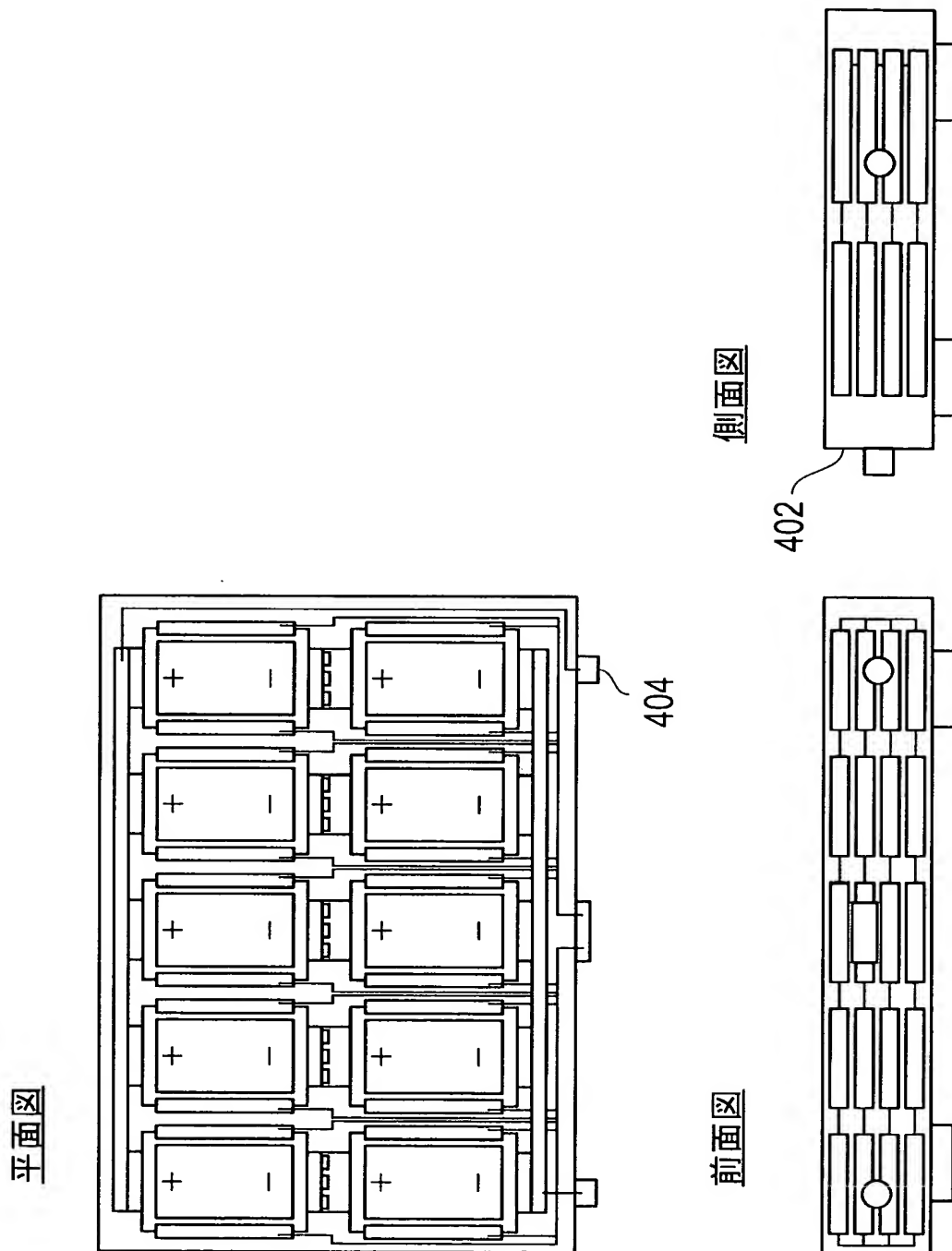


[FIG. 4]

PLAN VIEW OF ASSEMBLED BATTERY

FRONT VIEW OF ASSEMBLED BATTERY

SIDE VIEW OF ASSEMBLED BATTERY



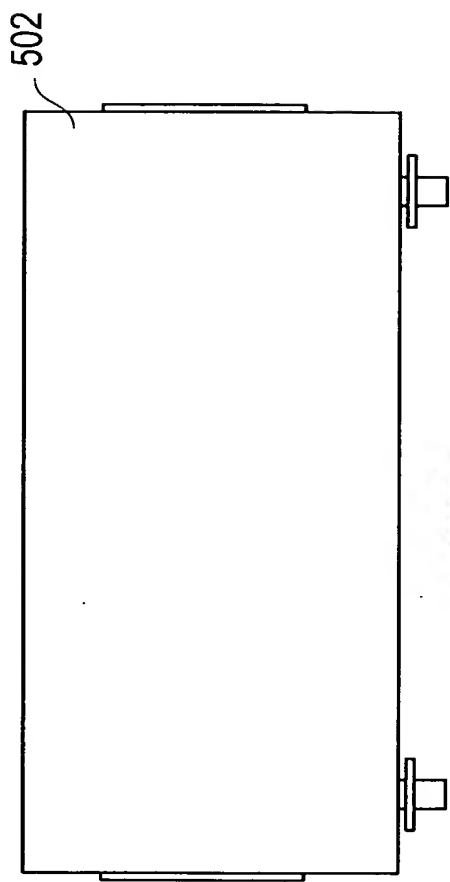
[FIG. 5]

PLAN VIEW OF MULTIPLE ASSEMBLED BATTERIES

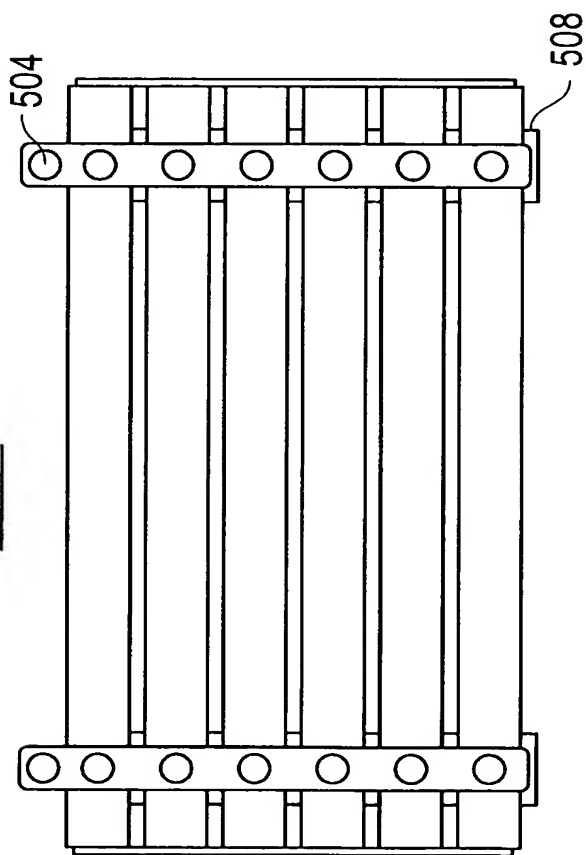
FRONT VIEW OF MULTIPLE ASSEMBLED BATTERIES

SIDE VIEW OF MULTIPLE ASSEMBLED BATTERIES

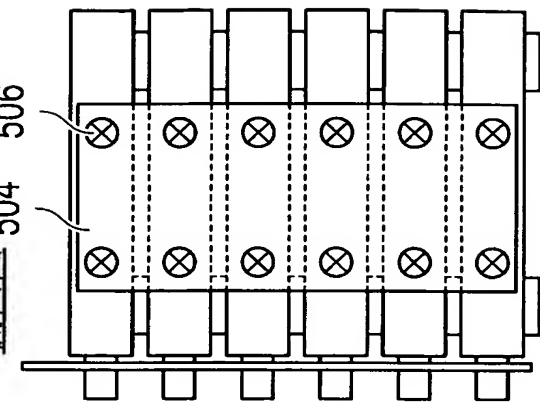
平面图



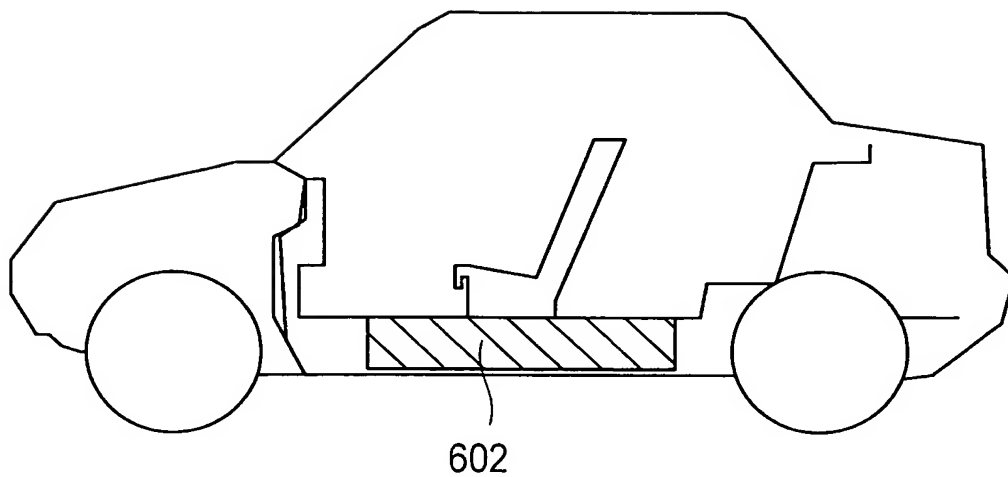
前面图



侧面图



[FIG. 6]



[FIG. 7]

VIBRATION TRANSMISSION RATE (dB)

FREQUENCY: Hz

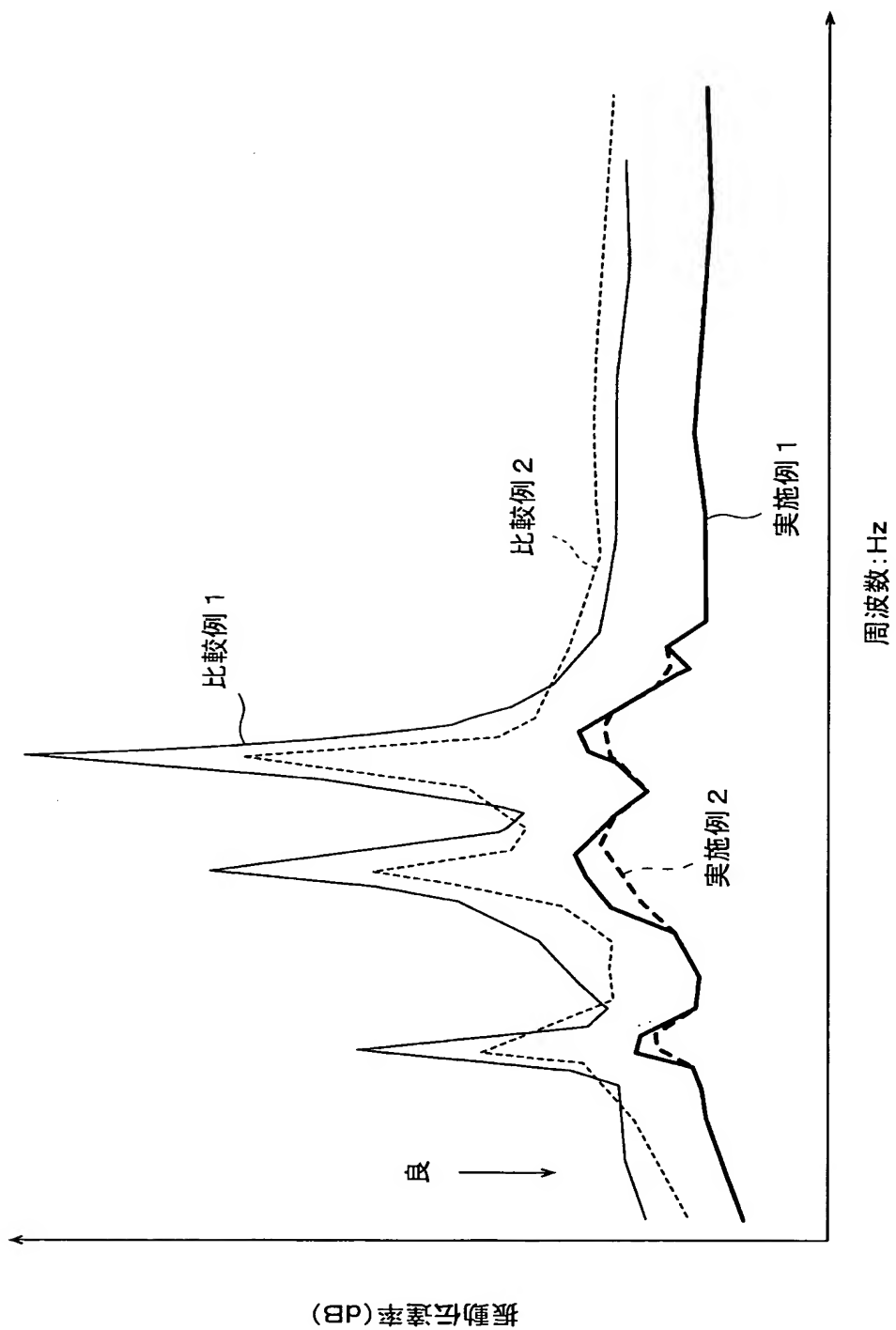
GOOD ↓

COMPARATIVE EXAMPLE 1

COMPARATIVE EXAMPLE 2

EMBODIMENT 2

EMBODIMENT 1



[DOCUMENT TITLE] ABSTRACT

[ABSTRACT]

[PROBLEM] To provide an electrode which is thin as well as high in

uniformity of film thickness.

[MEANS FOR THE SOLUTION] The above-described problem is solved by an electrode comprising a collector 104 and an electrode layer 102 which is formed by being laminated on the collector 104 and contains an active material, wherein the electrode having average thickness of an electrode plane, which defined as a portion where the collector 104 and the electrode layer 102 are laminated, is 5 to 300  $\mu\text{m}$ , and the maximum thickness of the electrode plane is 105% or less of the minimum thickness of the electrode plane. Such electrode can be produced by forming the electrode layer by use of an inkjet method.

[SELECTED DRAWING] FIG. 1